Energy fraction of CO_2 laser absorbed in EUV source plasma

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Our research plan for >6% CE

- Radiation hydrodynamic simulation shows that only 50 – 70% of an incident CO_2 laser energy is absorbed even in a high-CE (3 – 4%) EUV source plasma. Laser absorption must increase for >6%

← Non-absorbed laser energy will be measured with an integral sphere to validate the calculation by a radiation hydrodynamic simulation.

← Angular distribution of non-absorbed CO_2 laser energy will be measured to identify the physical mechanism of laser absorption/scattering in a plasma.

- Measurement of absorbed CO_2 laser energy in a pre-expanded droplet

← To validate enhancement of laser absorption in a long-scale rarefied plasma.

- Control of droplet expansion by changing laser pulse duration, wavelength, and irradiation geometry.

← Measurement of density profile of a expanded droplet with CO_2 laser shadowgraph.

- Characterization of high-CE EUV source plasma

← Measurement of density and temperature of high-CE EUV source plasma for benchmarking radiation-hydrodynamic code.

Facility upgrade

Pulse CO_2 laser (sub-J/100 ns) and pulse OPO laser (2 μm-wavelength) are now installed.

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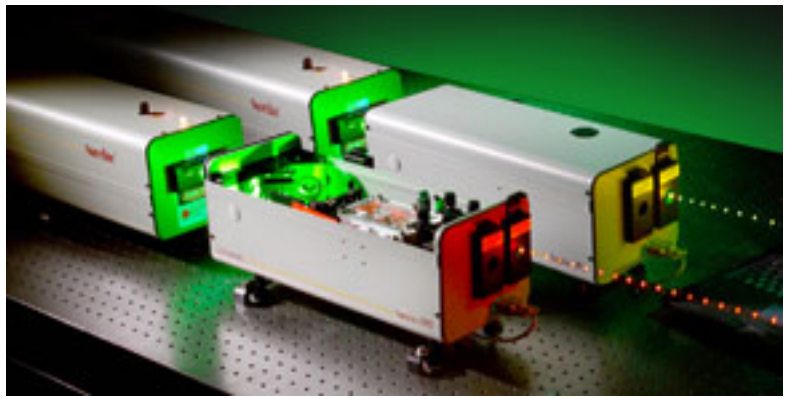
Pulse CO_2 laser

GAM
Wavelength: 9.3 μm/10.6 μm (changeable)
Energy/Duration: 650 mJ/100 ns
Reputition: single shot ~ 100 Hz
Near field pattern is controllable.

Pulse OPO laser



Coherent
Wavelength 0.7 ~ 2.5 μm (tunable)
Energy/Duration 25 mJ/4 ns @2 μm
Repeation single shot ~ 10 Hz

Absorbed energy measurement

Only 40 – 70% of the incident CO_2 laser energy is absorbed even in a high-CE EUV source plasma.

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Relation between absorbed energy fraction and EUV-CE

sim #	Condition	Laser abs.	EUV CE(%)
56	Confidential	40.2 (%)	2.49
59		50.2	3.21
60		49.4	3.25
61		50.9	3.30
62		62.0	4.15
63		72.0	3.77

Do we have a margin enough for 6%?

Absorbed energy measurement

Absorption laser energy will be measured with an integration sphere for CO_2 laser.

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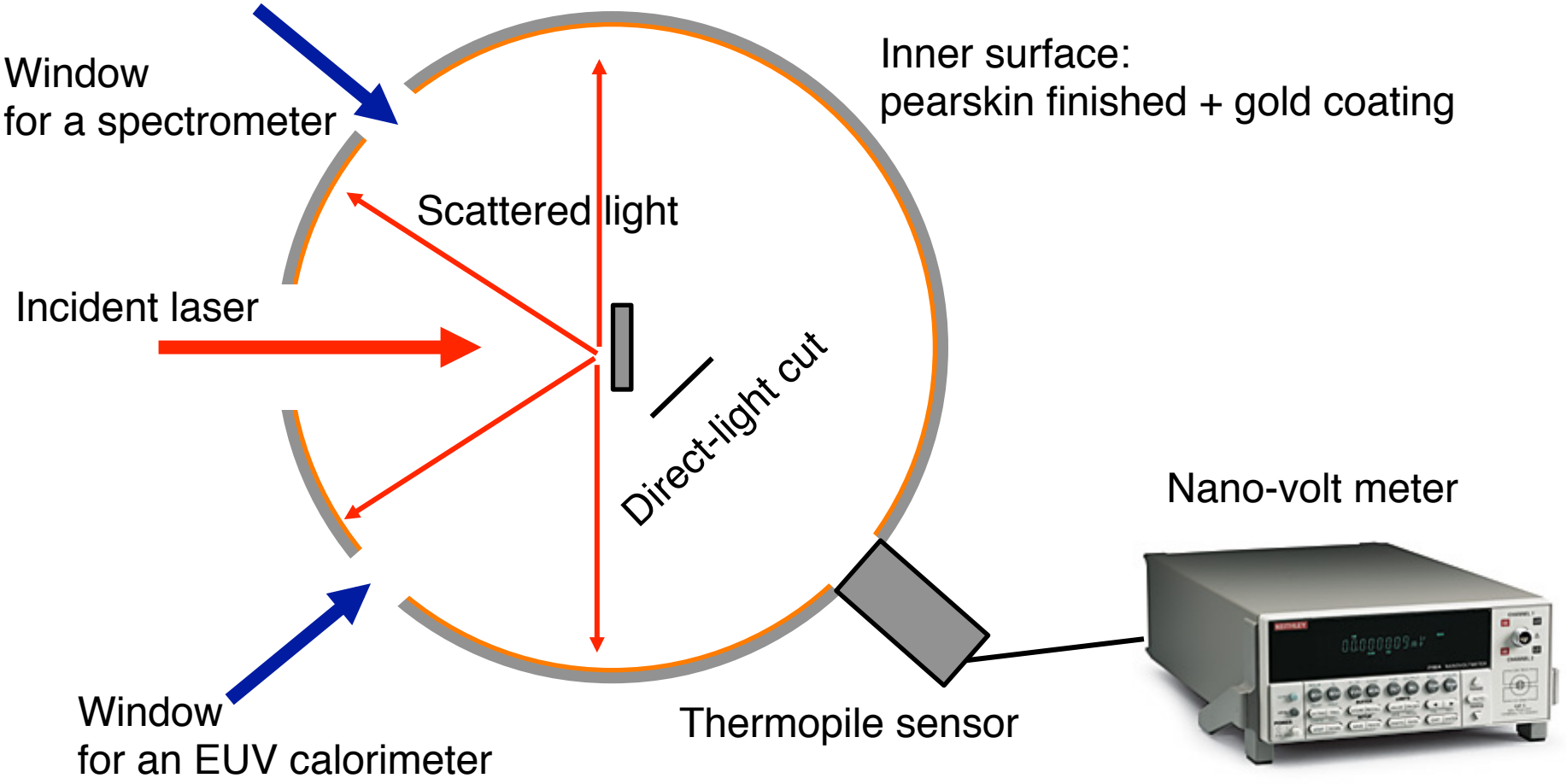
Absorption fraction measurement with an Integration sphere



EUV-CE and absorption fraction can be measured simultaneously.

Absorbed energy measurement

Angular distribution of scattered CO_2 laser will be measured with themopile sensor array.

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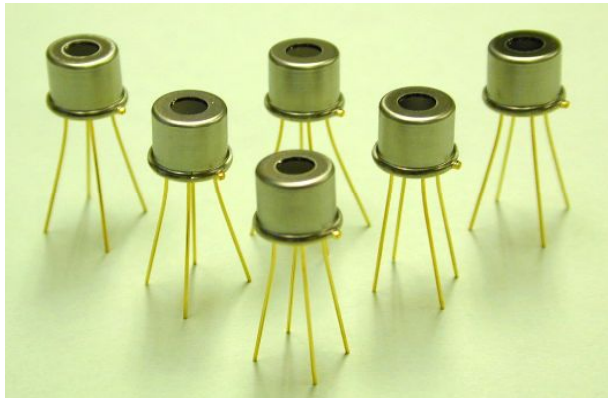
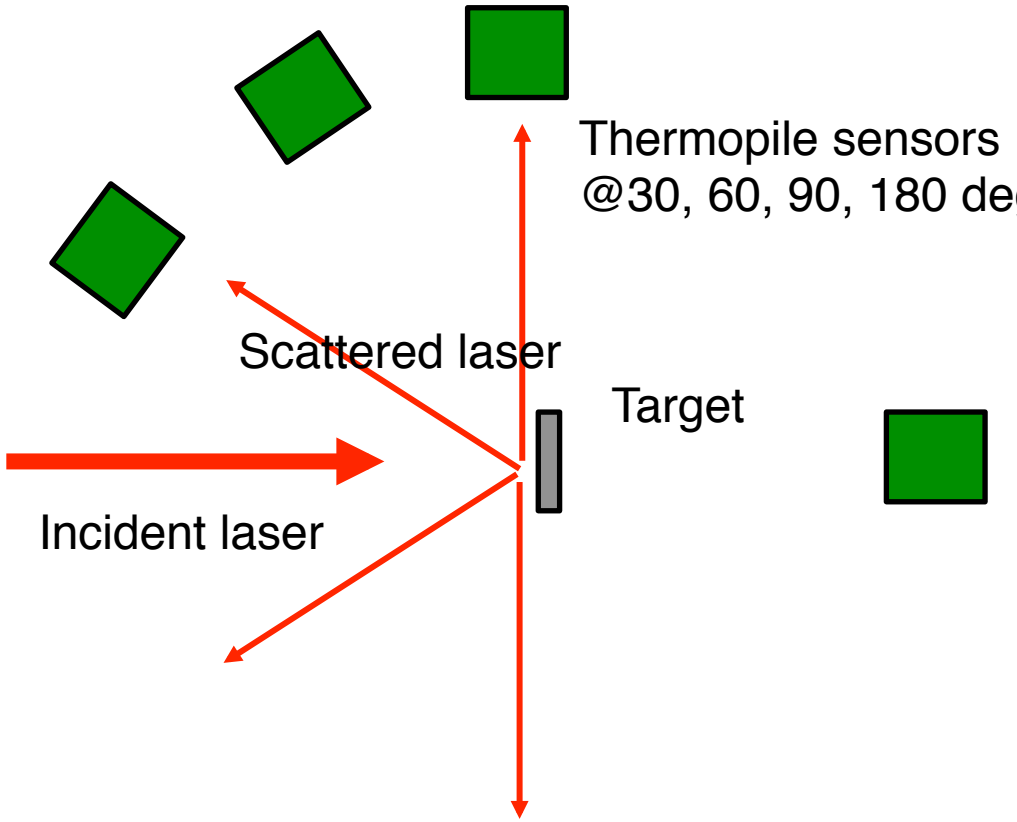
Themopile sensor



Piled thermocouple device
Sensitive only for 6.4 – 14 μm

Angular distribution measurement with themopile sensor array



Angular distribution is essential to identify scatter mechanism.

Optimization of droplet explosion

Density profile of CO_2 laser absorption region can be probed with a CO_2 laser shadowgraph.

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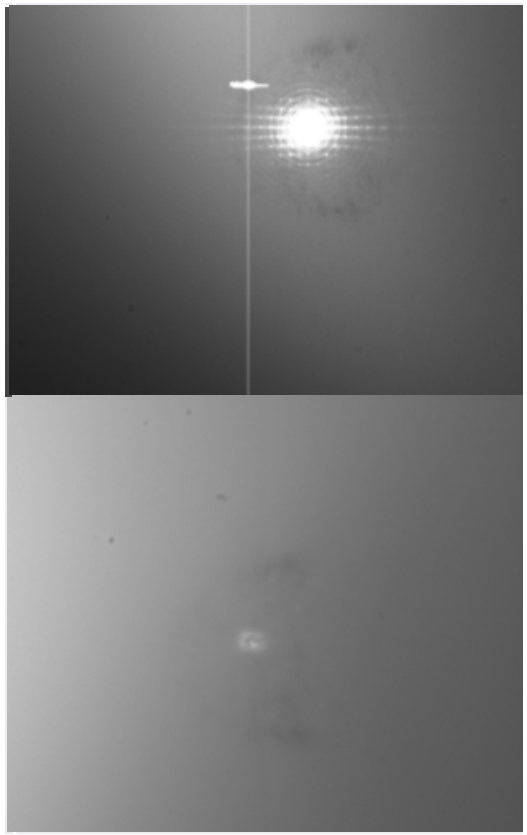
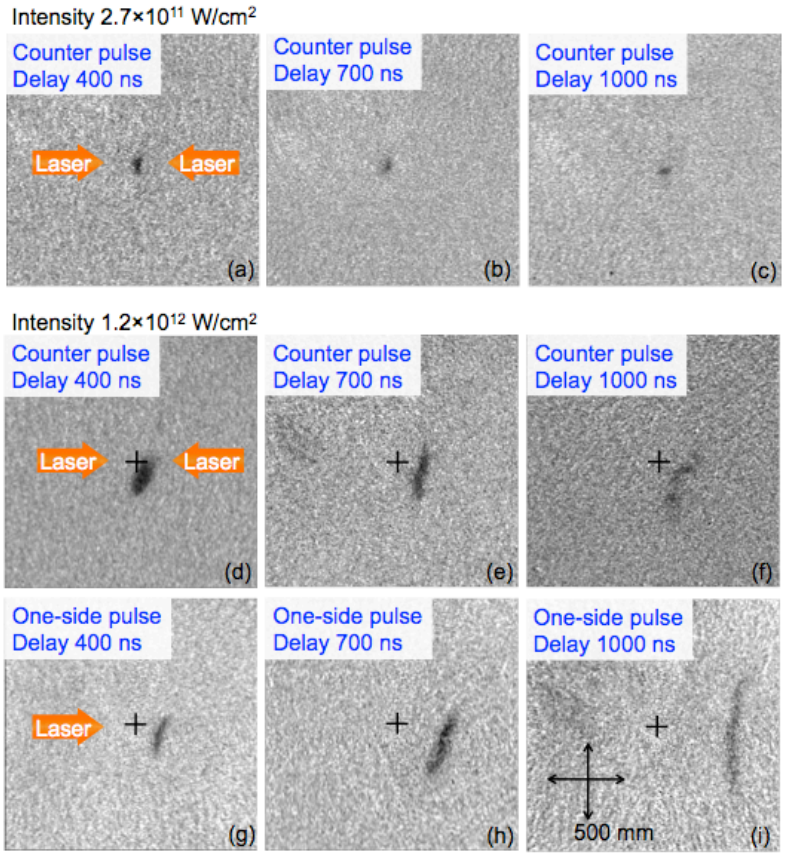
Visible light shadowgraph @GP



1.2 keV x-ray shadowgraph @Osaka Univ.



"Pyrocam" detector will be used for CO_2 shadowgraphy.

CE, absorption, density, and temperature will be measured simultaneously to establish guideline to >6%.

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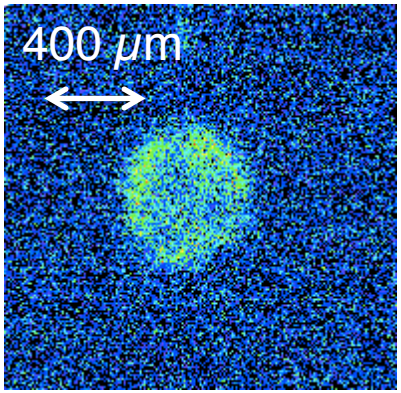

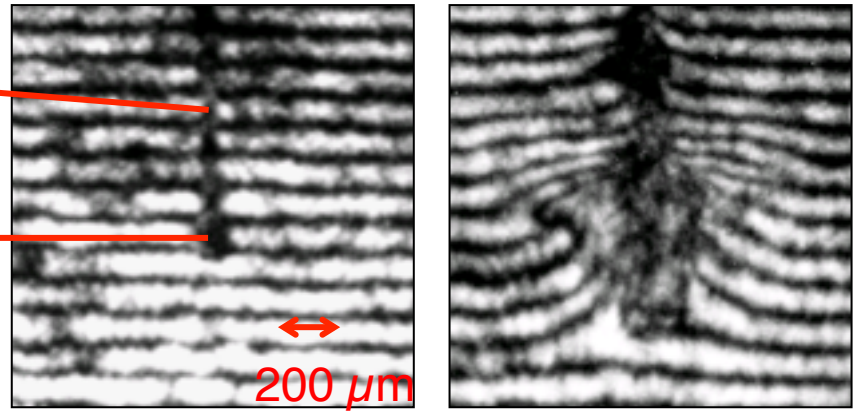

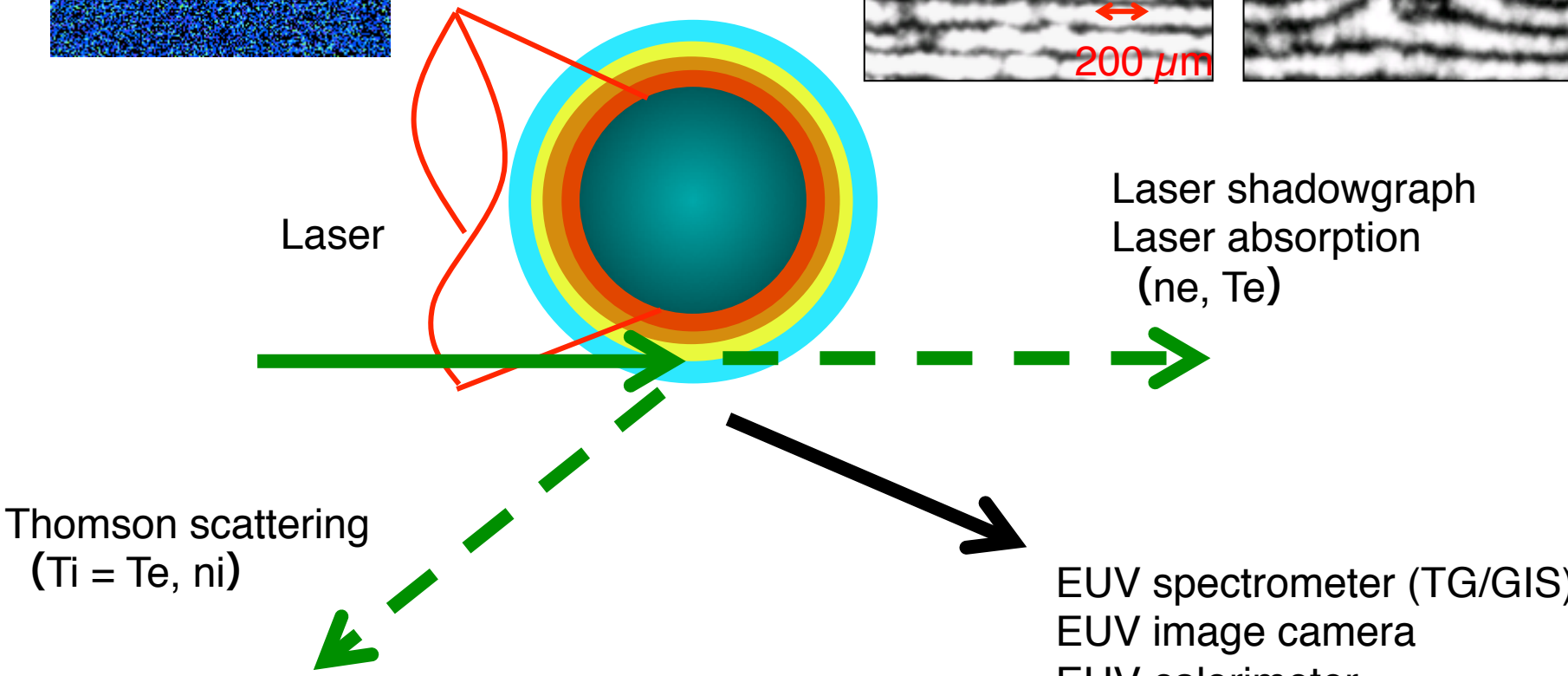

Items	13 Q2	13 Q3	13 Q4	14 Q1	14 Q2	14 Q3	14 Q4	15 Q1	15 Q2	15 Q3	15 Q4
OPO laser	Install	Operation									
CO_2 laser		Install	Operation								
Integral sphere	Design	Fab.	Install	Test	Operation						
Angular distribution	Design	Fab.	Install	Test	Operation						
Visible light backlight			Design	Install	Operation						
CO_2 laser backlight				Design	Install	Operation					
Optimization of pre-expansion						Try & Error				Optimized	
High-Rep droplet						Design	Fab.	Intro		Operation	
Integration experiment										Experiment	